

ABSTRACTS OF THE FOURTEENTH ANNUAL SCIENTIFIC RESEARCH MEETING



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May 12-13, 1988
Great Smoky Mountains National Park
Gatlinburg, Tennessee



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Cover photograph: Stream electrofishing survey on Cataloochee Creek, Great Smoky Mountains National Park. (NPS photo by Stephanie Gibert)

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Abstracts of the
FOURTEENTH ANNUAL SCIENTIFIC RESEARCH MEETING

of the Upland Areas of the Southeast Region
National Park Service

May 12-13, 1988
Park Headquarters
Great Smoky Mountains National Park
Gatlinburg, Tennessee

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LONG-TERM RESEARCH AND MONITORING STRATEGIES FOR GREAT SMOKY MOUNTAINS NATIONAL PARK

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Great Smoky Mountains National Park has been a center of scientific study throughout its entire 50-year history. With the establishment of the Uplands Field Research Laboratory, research in the park has intensified to the point where, today, there are many studies being conducted by park scientists, as well as many independently-funded, multidisciplinary research projects involving a multitude of outside scientists and research institutions. Studies in the spruce-fir forests concerning air pollution and its related effects have provided an opportunity to gather multidisciplinary research information on one of our key ecosystems. These efforts, including the Integrated Forests Study being conducted by Oak Ridge National Laboratory and the Spruce-Fir Research Cooperative coordinated by the USDA Forest Service, provided inspiration to develop a strategy to establish a long-term ecological research and monitoring program at Great Smoky Mountains National Park.

This is no easy task. The landscape is a mosaic of complex patterns of vegetation and soils. There are no ready answers on how to establish such a program. In order to address this difficult task, we will be soliciting many of the leading scientists in the region to participate in the establishment of a long-range plan for the program. These scientists will be on a steering committee and will not only help us scope the program but will help us develop specific protocols for the in-house elements of the program to be conducted by the staff of Great Smoky Mountains National Park.

In addition, the steering committee will solicit interest in their home institutions for participation in the program. The committee will help recruit scientists to participate in developing specific research proposals for funding by sources outside the National Park Service, such as the National Science Foundation, the Electric Power Research Institute, and Environmental Protection Agency.

What we are trying to accomplish is an institutional mechanism whereby scientists feel welcome to participate in long-term ecological research in the Park, where the data from these studies are properly curated, and the research sites themselves are adequately managed to avoid destructive science by one individual which could limit the use of the site by others. The National Park Service should be the steward of the research sites, the coordinator of research to be conducted on these sites, and curator of the resulting data. We want to form a solid bond with the very rich community of research institutions and leading scientists in the Southern Appalachians so that together we can accomplish the very ambitious goals for this program.

RESEARCH AT LAND BETWEEN THE LAKES

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Land Between the Lakes (LBL) was created in 1964 with a rather unique mission of being a national demonstration for developing innovations in outdoor recreation, environmental education, and integrated natural resource management. Much of the demonstration mission implies research and testing. In an effort to initiate more research activity at LBL, a Demonstration Development Unit was established in 1986 with two coordinators for research and professional development. Research arrangements are made primarily through university contacts and cooperative associations with other state and federal agencies. Presently there are nearly 50 projects ongoing, of which half are thesis-level research. Most projects are in the natural sciences with efforts toward arranging for more projects in the social sciences. Although independent and basic research projects are numerous, projects most encouraged are those which are long term, applied, and/or collaborative. Projects of this nature are best suited for demonstrational purposes.

NUTRIENT CYCLING PATTERNS IN RED SPRUCE FORESTS NEAR CLINGMAN'S DOME, GREAT SMOKY MOUNTAINS NATIONAL PARK

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Intensive nutrient cycling studies are being conducted in two red spruce forests near Clingman's Dome as part of the Integrated Forest Study. Of particular interest is the degree to which acid deposition is affecting the rate of nutrient leaching and soil solution Al^{3+} concentration in these forests. The cation composition of soil solutions from these sites is dominated by Al^{3+} (up to 70 $\mu\text{mol/L}$) and the anion composition is dominated by NO_3^- and SO_4^{2-} . The dominance of Al^{3+} is a natural consequence of the presence of the mineral acid anions (NO_3^- and SO_4^{2-}) in solutions passing through these extremely acid soils (<10% base saturation, sum of cations method). The source of SO_4^{2-} seems to be quite clearly atmospheric, whereas the source of NO_3^- is both atmospheric and from soil mineralization. Forest floor and soil N contents are high (near 10,000 kg/ha) and estimated mineralization rates in the soil range from 30 to 45 kg N/ha annually. In contrast to N, soil total Ca contents are quite low (<2500 kg/ha), as are soil exchangeable Ca^{2+} , K^+ , and Mg^{2+} . Preliminary estimates of leaching flux indicate that these ecosystems are showing a net loss of base cations, even though soils are already extremely acid.

Research supported by the Electric Power Research Institute under contract RP-2621 with Martin Marietta Energy Systems, Inc., under contract no. DE-AC05-84OR21400 with the U.S. Department of Energy.

STAND STRUCTURE AND GROWTH IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK: WHITTAKER'S PLOTS REVISITED

Robin L. Graham, Louis R. Iverson¹, Elizabeth A. Cook¹, and Jerry S. Olson², Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831

Changes in stand structure and growth between 1959-1960, 1977, and 1986 were evaluated for 8 stands ranging in elevation from 610 m to 1310 m in the Great Smoky Mountains National Park. These stands, which were originally investigated in 1959-1960 by R. H. Whittaker and reported in Whittaker (1963 and 1966), have varied species composition and disturbance histories. None of the stands changed appreciably in species composition over the 27-year interval. Stand diameter distribution stayed constant in the three old-growth undisturbed stands (a low-elevation cove forest, a high-elevation hemlock/rhododendron forest, and a high-elevation cove forest). The two young regenerating stands (a low elevation tulip poplar stand and a low elevation pine stand) showed a marked shift from many small diameter trees to fewer larger diameter trees. The three disturbed all-age stands (a mid-elevation chestnut oak stand, a mid-elevation hemlock-mixed hardwood, and a high elevation pine-heath stand) also shifted towards fewer but larger trees. Stand basal area and aboveground tree biomass increased in the young regenerating stands, increased or remained constant in the undisturbed old-growth stands, and decreased in 2 of the 3 disturbed stands. In comparing Whittaker's values for aboveground stand productivity and basal area increment of surviving trees between 1950 and 1960 with our values for the time interval between 1977 and 1986, we could find no clear trends related to disturbance history or elevation. The stands did appear to be converging on a common relationship between aboveground stand productivity and aboveground stand biomass.

References:

- Whittaker, R. H. 1963. *Ecology* 44:176-182.
Whittaker, R. H. 1966. *Ecology* 47:103-121.

¹ Illinois Natural History Survey, Champaign, IL 61820

² Global Patterns Associates, Lenoir City, TN 37771

Research performed under Work for Others Agreement No. ERD-85-509 with the University of Illinois and with Martin Marietta Energy Systems, Inc., under contract DE-AC05-84-R21400 with the U.S. Department of Energy.

ALUMINUM MOBILIZATION SIGNALS AND APPARENT CHANGES IN ALKALINE EARTH UPTAKE IN GSMNP TREES¹

E. A. Bondietti, C. F. Baes III and S. B. McLaughlin, Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831

Concentration ratios of aluminum to calcium, magnesium, and other divalent cations in increment cores obtained from red spruce and eastern hemlock trees growing in the Great Smoky Mountains National Park² changed in an unprecedented manner during the last 15-40 years. The timing of the change is contemporaneous with the rapid rise in sulfur emissions in the region, starting in the 1940s. These trends in wood concentrations are interpreted as indicating that on a large scale these trees have experienced an increase in the availability of soil aluminum, as would be expected from the mobilization of exchangeable aluminum by sulfate and/or nitrate deposition into the extremely acid soils in the park. Many of the red spruce and hemlock cores also showed an inverse relationship between radial growth and Al:Ca ratios, indicating that increasing aluminum availability coincides with or is linked to radial growth declines.

Increases in the concentration of soil solution aluminum relative to calcium or magnesium have been demonstrated to reduce the growth of grasses, legumes and trees. The potential impact of increasing the ratio of aluminum to calcium and magnesium in the soil solutions of 100- to 200-year old trees is to reduce the availability of calcium and magnesium, potentially interfering with physiological functions requiring the presence of these elements. Calcium is particularly important for apical, root, and vascular meristematic activity (calcium). This raises several questions: has aluminum mobilization interfered with the alkaline earth nutrition of these very old trees? Is calcium now a limiting nutrient for growth?

¹ Research sponsored by the Oak Ridge National Laboratory and the Electric Power Research Institute (RP-2621). Oak Ridge National Laboratory is operated by Martin Marietta Energy Systems, Inc., under Contract No. DE-AC05-84OR21400 with the U.S. Department of Energy.

² C. F. Baes III and S. B. McLaughlin, 1986. Multielemental Analysis of Tree Rings: A Survey of Coniferous Trees in the Great Smoky Mountains National Park. Report ORNL-6155 (National Technical Information Service, Springfield, Virginia).

INTERACTIVE EFFECTS OF NATURAL AND ANTHROPOGENIC FACTORS ON THE GROWTH AND PHYSIOLOGY OF RED SPRUCE IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK

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Red spruce (*Picea rubens* Sarg.) occurs throughout New England and at high elevations along the Appalachian Mountains in the southeastern United States. Radial growth analysis of dominant and codominant trees shows an unprecedented regional decline in growth during the last 30 years. The decline, which increases with elevation in the southeast, represents a departure from typical growth-climate relationships which occurred previously. It has been suggested that the recent growth decline has been triggered by increased levels of atmospheric pollutants, which may affect red spruce growth either directly or indirectly.

Field and laboratory studies are currently underway to characterize physiological changes associated with the decline of red spruce at high elevations in the Great Smoky Mountains National Park. The research strategy is to document the magnitude of growth changes at sites experiencing varying degrees of growth decline and to explore the physiological basis of the observed differences. The objective of this approach is to evaluate likely mechanisms of action and principal causative factors for observed growth patterns. Controlled laboratory experiments are being conducted concurrently to evaluate seedling response to specific pollutants.

During 1987, two field sites were established (high site, 1935 m; lower site, 1720 m) on Clingman's Dome, Tennessee. Each site is similar in under and over-story composition, and sapling-sized red spruce and Fraser fir (*Abies fraseri* [Pursh] Poir.) are the dominant tree species in the understory. Mature red spruce on the upper elevation site show radial growth decline during the last 25 years, similar in magnitude to declines reported at other high elevation sites (McLaughlin, et al., *Oecologia* 72:487-501, 1987). Radial growth decline is less severe at the low site and appears to be restricted to the last 5 years. Growth analysis of saplings revealed that relative height growth at the low elevation site has been approximately 68% greater than at the high elevation site during the last 6 years.

Several physiological factors were elevated during the first field season, including net CO₂ exchange rate, dark respiration, branch level ¹⁴C partitioning patterns, plant water relations, soil and tissue nutrient status, and root alterations in whole-plant carbon dynamics, including reduced photosynthesis and increased respiration, are primary factors reducing growth at the high elevation site. The roles of delayed winter hardening and high foliar aluminum levels associated with slower growth at the upper elevation site are also being explored.

Research sponsored by the USDA Spruce-Fir Research Cooperative Program under Interagency Agreement 1594-1594-A1 with the U.S. Department of Energy under Contract No. DE-AC05-84OR21400 with Martin Marietta Energy Systems, Inc. Senior author was supported in part by an appointment to the Laboratory Cooperative Postgraduate Research Training Program administered by Oak Ridge Associated Universities.

SPRUCE-FIR REGENERATION AT THREE SOUTHERN APPALACHIAN SITES

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During the past three years, seedfall, seed viability, germination, seedling and understory growth, and overstory mortality have been measured at 136 plots among three study sites (Mt. Rogers National Recreation Area in Virginia, the Black Mountains of North Carolina and the Great Smoky Mountains of North Carolina and Tennessee) to determine if regeneration patterns are influenced by pollution deposition gradients in addition to the past logging disturbance and the large-scale infestations of the balsam woolly adelgid (*Adelges piceae* Ratz.).

Spruce and fir regeneration densities follow similar elevation gradients as observed for overstory stems and have proportional densities to overstory levels. As elevation increases, red spruce (*Picea rubens* Sarg.) regeneration densities tend to decrease and Fraser fir (*Abies fraseri* [Pursh] Poir.) densities tend to increase. The mostly primary growth stands of the Great Smokies have much lower understory densities than in the second growth stands of the other two study sites.

After overstory canopy removal at lower elevation sites, successional hardwoods invade in high numbers. The balsam woolly adelgid has caused significant mortality of overstory fir, but the insect was found to have little impact on the health of understory fir.

AN ECOLOGICAL OVERVIEW AND PLANT COMMUNITIES OF THE BEAR CREEK NATURAL AREA, STEWART COUNTY, TENNESSEE

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The Bear Creek Natural Area is a 325-ha site within the TVA-managed Land Between the Lakes, a conservation, education and recreation facility in western Kentucky and Tennessee. The area is topographically diverse, with habitats ranging from several wetland types to mesic-dry upland forests. It has been named a State Natural Area in accordance with the Tennessee Natural Areas Preservation Act, is a TVA Natural Area, and is under consideration for designation as a National Natural Landmark by the National Park Service.

The impressive cultural history of the area includes occupation by early Indian groups, regular usage for hunting by later tribes, and settlement in the late 1700s by Revolutionary War veterans who received land grants for services. This was followed by an iron industry era, a Civil War legacy, and then a low-population farming region prior to governmental purchase in 1963.

A floristic list of 733 vascular species (610 native and 123 introduced), representing 388 genera and 111 families, was published by the authors in 1987. Four families, Asteraceae (85 species), Poaceae (83), Cyperaceae (44), and Fabaceae (39) account for 34 percent of the flora. Outstandingly large genera are Carex (25 species), Quercus (14), Solidago (10), and Aster and Panicum (9 each). The 136 woody species, consisting of 67 trees, 46 shrubs and small trees, and 23 woody vines, make up 19 percent of the flora with taxa of Quercus (14) and Carya (7) dominating.

In addition to the unusually large and diverse vascular flora and the variety of habitats, the area is botanically and ecologically significant for a number of other reasons, including:

1. The mesic slope and ravine forests represent the mostly decimated western form of the Mixed Mesophytic Forest and contain a high percentage of sugar maple (Acer saccharum) and American beech (Fagus grandifolia) with some basswood (Tilia heterophylla).

2. The old-growth protected forests are especially meaningful. Although secondary, there is little evidence of anthropogenic influence and recovery has progressed naturally since the early 1960s.

3. Eleven species are listed as rare, threatened, or endangered. The most important are bugbane (Cimicifuga rubifolia) and valerian (Valeriana pauciflora), both under Federal review.

4. Several species are near the limits of their natural ranges. Woody examples include Ohio buckeye (Aesculus glabra) and white walnut (Juglans cinerea). Herbs include the Allegheny spurge (Pachysandra procumbens) and prairie rattlesnake root (Prenanthes barbata). Disjunctions are shown by such taxa as mosquito fern (Azolla caroliniana), separated from its main range in the Mississippi River Valley, and red buckeye (Aesculus pavia), disjunct from its range to the west and south.

The Bear Creek Natural Area is also a significant site for long-term ecological research and monitoring as maturity occurs in the absence of anthropogenic influences. Preliminary data on community composition and plans for continuing studies will be further discussed.

PAULOWNIA TOMENTOSA AND MICROSTEGIUM VIMINEUM: UNWANTED EXOTICS IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK

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Some species of plants native to the Great Smoky Mountains National Park are threatened by introduced species which aggressively occupy sites which they invade. Two exotic species, Microstegium vimineum and Paulownia tomentosa, have been studied in attempts to determine methods of control and to understand their life histories with special emphasis on their seed vectors and their phenology.

Both species have undergone phenological observations at a variety of sites and elevations. We believe that we may be able to set the best date for chemical or other treatment by using the dates of flowering, for example, as guides for optimal treatment date. Studies are also underway to determine how many years Microstegium can remain stored in the surface soil and yet germinate. Seed traps are in place to determine when seeds are shed.

Both species have been subject to various chemical phytocides in attempts to determine one or more that is physiologically effective as well as environmentally safe. Final measurements of the first year's work will be available in August of 1988, which will allow two years for chemicals to take effect. In the meanwhile, treatments will be made in 1988 to replicate the apparently best of those that were made in 1987.

EFFECTS OF OZONE ON YOUNG FRASER FIR

Richard T. Busing and Edward E. C. Clebsch, University of Tennessee, Knoxville, TN 37901

Growth chamber experiments were conducted to assess the effects of ozone on Fraser fir. First-year seedlings and 2-5 year seedlings were treated in closed chambers at ozone levels of 30 to 240 ppb for nine days, three hours per day. Visible foliar injury did not occur at any level. Root weight of the 2-5 year seedlings was low following the 240 ppb ozone treatment. An additional experiment involved balsam woolly adelgid and ozone treatments to saplings in open-top chambers. Adelgid-infested and uninfested saplings were subjected to four ozone levels (ca. 30, 45, 100 and 215 ppb) for 39 days. Again, no foliar injury was observed. No ozone-induced differences in plant weight or biomass allocation were detected. A low leaf to stem mass ratio was attributed to the adelgid, however. Interaction between ozone and the adelgid was not revealed in this short-term investigation.

ACIDIC DEPOSITION AND WINDFIELD IN THE MT. MITCHELL STATE PARK: 1986 AND 1987

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In Mt. Mitchell State Park, the decline of red spruce and Fraser fir forest is noticeable above the cloud base, which is frequently observed around 1,585 m above mean sea level (MSL). Acidic deposition by polluted cloud water is considered one of the causes for decline. In order to quantitatively assess the chemical climate of Mt. Mitchell State Park, we erected a 16.5-m tall aluminum walk-up tower and instrumented it with an electronic weather station, cloud water collectors and gaseous analyzers at Gibbs Peak (2,006 m MSL). Chemical analysis has shown sulfate and nitrate, which formed mostly by sulfur and nitrogen originally, as the most important chemical compounds which contribute to high acidity in cloud water. Synoptic scale patterns are responsible for the transportation of these pollutants. Using the EPA inventory of National Emission data in 1985, emission sources are categorized into 3 wind sectors: (1) wind sector 1 ranging from 290° to 65°, (2) wind sector 2 ranging from 66° to 210°, and (3) wind sector 3 ranging from 210° to 290°. We found the airmasses traversing from sector 1 were responsible for the highest acidity (pH=3.08 in 1986 and pH=3.62 in 1987) of cloud water. Because the local windfields were strongly affected by synoptic wind during cloud events, the acidic deposition can be considered as a function of wind direction measured at site. When the results of acidic deposition were plotted as a function of wind direction and related to the back trajectories of airmasses, a better understanding of the sources of pollutants producing the acidity in cloud water was evolved. The pollutants emitted from Illinois, Indiana and Ohio, which are conventionally the highest emission areas in the eastern United States, were found to be responsible for the highest acidity in cloud water. Since it is known that exposure to water with pH between 2 and 3 has a potential of damaging the plants, our results are the first to point out that such low values can be realized under certain windfields in Mt. Mitchell State Park, especially during formative and evaporative stages of clouds.

OZONE EFFECTS PROGRAM IN GREAT SMOKY MOUNTAINS NATIONAL PARK

Howard S. Neufeld, Appalachian State University, Boone, NC 28608; Jim Renfro and David G. Silsbee, Uplands Field Research Laboratory, Great Smoky Mountains National Park, Gatlinburg, TN 37738

Ozone is recognized as the major air pollutant in the United States. Recent monitoring efforts in and around Great Smoky Mountains National Park have shown that ambient ozone amounts can exceed levels known to affect plant growth and appearance under controlled conditions. However, it is not clear whether these same levels can affect plants native to the park, few of which have been investigated for their responses to elevated ozone.

To better understand the potential impacts of ozone on native plants, a two-fold project is now underway, involving (1) exposing various native plants to controlled levels of ozone, and (2) monitoring plant responses at three permanent stations where ozone levels are continuously recorded.

Open-topped chambers will be used to expose plants to 3 levels of ozone: low ozone (charcoal-filtered air), medium ozone (simulated 7-day exposure profile from Look Rock Monitoring Station data), and high ozone (twice the ozone in the medium treatment). Both herbaceous and woody plants native to the park will be exposed during the growing season. Woody plants will be exposed for two seasons to assess potential carry-over effects. Foliar effects, along with growth and productivity, will be measured.

Plants at the permanent monitoring stations (Cove Mt., elev. 1219 m; Look Rock, elev. 823 m; and Uplands Research Lab, elev. 597) will be monitored for potential ozone injury on a regular basis and checked after significant ozone events. A fourth station will come on line this year at Clingman's Dome (elev. 2012 m). Potential ozone injury will be compared to that obtained in the fumigation chambers for verification purposes.

Future improvements in the program will hopefully involve the screening of more species of plants, particularly herbaceous ones. In addition, physiological effects will be studied, including gas exchange and water relations. Reproductive effects need to be evaluated also. And the possibility that ozone interacts with other pollutants, such as acid rain or fog, should be tested.

Finally, more stations need to be included in the survey network, particularly in closed mid-elevation forests. Most of the stations are now on ridge tops. The spatial and temporal variations in ozone amounts need to be evaluated in these closed hardwood forests.

ATMOSPHERIC DEPOSITION OF NITROGEN AND SULFUR TO A HIGH ELEVATION STAND IN GREAT SMOKY MOUNTAINS NATIONAL PARK

David Silsbee, Uplands Field Research Laboratory, National Park Service, Gatlinburg, TN 37738; Steve Lindberg, Douglas Schaefer and James Owens, Oak Ridge National Laboratory, Oak Ridge, TN 37831

Measurements of atmospheric nitrogen and sulfur deposition at a high elevation spruce stand in Great Smoky Mountains National Park (GRSM) were presented and compared with similar measurements from seven other sites. The sites were operated as part of the Integrated Forest Study funded by the Electric Power Research Institute through Oak Ridge National Laboratory. A wide spectrum of forest types, geographic locations, and topographic positions were represented.

Similar measurement protocols were followed at all sites. Deposition of SO_4 , NO_3 , and NH_4 in rain and snow were measured directly. Concentrations of SO_4 , NO_3 , and NH_4 in cloudwater were measured, and deposition was estimated using several different methods to estimate cloudwater flux. Air concentrations of particulate SO_4 , NO_3 , and NH_4 , as well as SO_2 and HNO_3 vapor, were measured and deposition estimates developed using a computer model based on air concentrations, canopy structure data, meteorological data, and laboratory and literature derived deposition velocity estimates.

Results from the high elevation spruce stand in GRSM were compared to seven other sites, including low elevation southeastern sites, low and high elevation northeastern sites, and low elevation northwestern sites. Total deposition of both nitrogen and sulfur at the GRSM site was more than twice that of any other site. The greatest difference between sites was in cloudwater deposition, with cloudwater deposition to most sites being insignificant, and the GRSM site receiving over 10 times the input of any other site. Wet deposition of S and N at GRSM was similar to other eastern sites, with lower concentrations of S and N in precipitation in GRSM being balanced by larger quantities of precipitation. Dry deposition to the GRSM site was higher than other sites because of high wind speeds and the efficiency with which the high-leaf area, irregular canopy of the spruce stand was able to scavenge material from the air. Although N and S concentrations in the air were not as high as at some other sites, actual deposition to the canopy was higher.

PAST EXPERIENCE AS A FACTOR AFFECTING PREFERENCES FOR MANAGEMENT ACTION

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This study proposes three methods of differentiating between river users. It then looks at attitude differences between those users towards potential management actions and tests the hypothesis that the attitudes of the more experienced user are different from the attitudes of the less experienced user. River users were surveyed on the Big South Fork River and Obed River in Tennessee. They were differentiated by (a) craft type (raft, canoe, kayak), (b) past experience (novice, beginner, casual, committed, life-style), and (c) style of participation (collector, local, balanced). Twenty-six questions about management action reflected opinions about facility improvement, management services, regulations, and crowding controls. Results showed the craft type and past experience methods of differentiation were highly correlated and identified the same groups of users. The more experienced users were the canoers and kayakers and the less experienced users were the rafters. This only supports the obvious and indicates that future studies must construct past experience scales for a single craft type rather than for all river users. Results also showed the more experienced user favors a pristine environment and, unlike past studies, opposes crowding controls. This indicates the lack of a crowding problem and an interest in maintaining a non-regimented experience. This shows these rivers to be in an earlier stage of recreational succession. While past experience and style of participation are overly subjective and only moderately effective differentiating methods, we do see a clear illustration that river users are not a homogeneous group. By understanding the distinctions between river users, we are better able to avoid biases in policy decision and management action.

RECREATION RESOURCES, CONDITIONS AND USE IN ONTARIO PROVINCIAL PARKS

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The research analyzed the recreation use pattern in 110 provincial parks in Ontario. Fifty different factors (including natural resources, cultural heritage, geographical conditions, recreation facilities, etc.) were examined in order to explain variations in the recreation use pattern. The importance of each factor was quantified, and regression models were established to predict recreation use.

The research showed that the differences in recreation resources and conditions among the parks were the principal explanations for the variation in recreation use from park to park. The recreation use pattern is dependent on recreation uses and conditions.

Recreation use in Ontario is different between southern and northern parks. On average, southern parks have more users, higher user densities, and higher proportions of day users than the northern parks. The reasons are that southern Ontario has a higher population density, warmer weather, a better developed transportation system, and a longer shoreline on the Great Lakes.

The length of beach, the number of access points, the potential population pressure, and the length of open season are the most important factors determining the number of users in a park. The number of campers is particularly dependent on the availability of facilities, such as campsites, comfort stations, showers, and laundromats, while the number of day users is more dependent on the landscape attractions, such as access to the Great Lakes, the land capability for wildlife, and the type of vegetation or bedrock (e.g., parks with sedimentary rocks tend to have more users than parks with igneous rocks).

The number of users in each park can be predicted by quantifying the recreation resources and conditions of the park. For each of the nine categories of recreation use, a five-variable linear regression model explained eighty percent or more of the total variation. The number of overnight campers was more accurately predicted by the regression models than the number of day users.

The results of this study can be used not only to interpret the variations in park use, but also to predict the future use for Ontario provincial parks.

ATTITUDE DIFFERENTIATION OF NATIONAL PARK VALUES

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One of the problems facing managers of heavily used recreation areas, such as the Great Smoky Mountains National Park, is balancing protection of the environment with accessibility to and use by the public. People come into natural recreational areas with a wide variety of expectations of what they will find and what they will do there. People also come in with great differences in the amount of knowledge they possess about the natural environment, which may affect the perceptions they have of a wilderness area. Some, such as a first-time visitor, may perceive wilderness as a frightening, foreign place; others, such as a park ranger or experienced hiker, may perceive it as a part of themselves and feel comfortable and at home in the wilderness.

The extent to which a person feels a part of the wilderness will most likely affect the attitudes held towards wilderness areas and the choice of behaviors exhibited in that environment. Additionally, the amount of knowledge about the natural environment and the amount of previous experience in a wilderness area will affect the choice of attitudes and behaviors, and may even affect a person's perception of "what's out there"--what a person actually sees in a wilderness environment. Those who know little about the natural environment will not be as aware of how their behaviors impact on the ecosystems of the park.

A series of studies is being conducted at the University of Tennessee examining this relationship between visitors' prior knowledge, attitudes, perceptions, experiences, and behaviors in wilderness areas. Preliminary results from two of these studies have been examined. Factor analysis of an attitude questionnaire revealed five major dimensions of a wilderness experience: (1) beauty and enjoyment, (2) active, involved participation, (3) educational experiences, (4) rules and regulations awareness, and (5) fear--mostly of animals. Content analysis of a sentence completion questionnaire revealed a number of response categories revolving around features in national parks, animals, activities, rangers and rules, conservation, and illegal activities. In general, attitudes towards most aspects of national parks were positive. Most people reported their purpose for going to parks was to relax, look at scenery, and socialize with friends or family. Animals in a park, particularly bears, were scary to 36.8% of the people surveyed. However, 25.3% thought it was all right to feed them and 7.4% thought they should be in cages. With regard to litter in a park, 42.1% expressed anger at seeing litter but only 7.4% said they would pick it up. In contrast, 26.3% said they would pick up litter in their neighborhood. Most thought conservation of natural resources is important, but 10.5% said they cut down trees for firewood in a park, and 7.4% dig up plants to take home. The majority of people felt that regulations are good, and the National Park Service does a good job.

THE FEASIBILITY OF USING BRUSHING TO DETER USE OF UNOFFICIAL TRAILS

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At Craggy Pinnacles on the Blue Ridge Parkway, intensive visitor use has opened networks of unofficial trails, initiating soil erosion and damaging clumps of endangered plant species. Since the site is covered by a dense heath dominated by Rhododendron catawbiense and Vaccinium spp., the trails tend to be made alongside rock outcrops, which offer unobstructed views and easy maneuverability for hikers. We attempted, during July 1987, to deter hikers by blocking fourteen sections of unofficial trail with heavy brush. Height, width, depth and visual permeability of the brush were recorded, and a rating was given for overall appearance as a physical and visual barrier. Materials included branches, collected dead or cut from live plants, and mountain ash, Sorbus americana, layered by cutting a limb halfway through and bending it across the trail to form a living hedge. If several stems are "layered" on top of each other, the path appears to dead-end in living vegetation.

Of the less substantial brushings, six were rated R3 (problematic but passable). They averaged 110 cm in height, 170 cm in depth and had an average permeability of 40%, measured by percent sky visible. The most substantial brushings, rated R5 (looks impenetrable), averaged 160 cm in height, 290 cm in depth and had an average permeability of 11%. Within a month, six of the fourteen brushings were completely dismantled and three others rendered ineffective. Three of the less formidable R3

brushings were dismantled in the first two weeks, rebuilt, and destroyed again. Two others were destroyed within four weeks. Within two months, nine of the 14 brushings were completely broken down and four others were rendered ineffective. Only one was undiminished. At this latter brushing and at one other, hikers detoured over rocks which harbored vulnerable rare plants, spreading damage to areas which were not previously trampled. Visitor monitoring on four weekend days during summer 1987 counted 444 people on Craggy Pinnacles. On one of the three networks of brushed trails, 20 people broke through the brush barriers.

Observations of visitor movements at Craggy Pinnacles indicate that although brushing may be useful to close unofficial trails, other measures are necessary to reduce incentives for bushwacking. These may include interpretation of fragile, high-elevation habitats, signing, closure of a main route through a particularly vulnerable area, and improved design of two overlooks (including construction of stone barriers), where much of the bushwacking originates.

APPLICATION OF PSYCHOLOGICAL PRINCIPLES AND RESEARCH METHODS IN NATIONAL PARKS

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Managers of the national parks are faced with the dual tasks of conserving and preserving their natural resources, while providing use opportunities for the public. These are conflicting missions, and the typical approach to meeting these directives is to structure use so that impact on natural resources is minimized. As a consequence, policy is place-oriented, and the data used to make policy are gathered through physical and biological science methods.

Ecological psychology has developed the concept of behavior setting, which recognizes that human behavior is determined by the person, by the place, and by the interaction of person and place. If park policy-makers consider this trilogy, then policy can be based on and implemented through any one or all three. Instead of maximizing conservation only, they can optimize both conservation and use. To do this, more research is needed which gets at the person aspects.

Use policy is often implemented in the form of restrictions on use, with consequences predicted by Iso-Ahola's studies of perceived freedom. When people are unable to do what they have planned, they feel a loss of freedom. The denied behavior becomes more attractive, they make direct attempts to pursue that activity, they engage in similar activities, and may react with frustration and anger. A person-oriented approach to use restriction might place the perceived loss of freedom on park personnel (I would like to let you camp here, but my boss won't let me overflow the campground), teach the user why the restriction is needed (Your jeep would erode the trail severely) so the user can choose not to make an adverse impact, and provide a number of alternatives for the user to choose from (and so feel in control again).

A person-place intervention is also proposed. Observation has shown that people hiking the Clingman's Dome tower trail in the Smokies rarely use rest benches provided. Several heart attack deaths have occurred there. The observers conclude that social facilitation or natural competitiveness may cause some hikers to climb faster with others present than they would if alone. Also, they may bypass the benches even when very tired because they fear they will be negatively evaluated by passers-by. It is felt that if the benches were sited in "nature study areas" off the trail, with educational materials to read, there would be less evaluation apprehension and people might be motivated to sit there. This would also provide a means of getting important "messages" supportive of park policy in the public view.

THE IMPORTANCE OF COMPETITION FOR FOOD RESOURCES IN THE INTERACTION BETWEEN BROOK TROUT AND RAINBOW TROUT

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The last 80 years have seen a drastic reduction in the range of the brook trout (*Salvelinus fontinalis*), the only salmonid native to the Southern Appalachians. Much of this range reduction is directly correlated with increases in the range of the introduced rainbow trout (*Salmo gairdneri*). The purpose of this study was to determine if competition for food resources plays a significant role in this interaction.

Stomach contents were obtained from sympatric and allopatric populations of brook and rainbow trout during June, July, August and September of 1987. Terrestrials comprised the majority of food items in the stomachs of adult fish from all populations, the mean percentage relative wet weight ranging from 59% in sympatric rainbow trout to 74% in sympatric brook trout. Comparisons using Schoener's Index of Dietary Overlap indicated that there was significant dietary overlap between all populations during the majority of the sampling dates. Analysis of variance indicated that there were no significant differences in the mean relative weight of stomach contents of adult brook trout in sympatry or allopatry, or between adult brook trout and adult rainbow trout living in sympatry. However, the mean relative weight of stomach contents in adult rainbow trout in allopatry was significantly lower than that in adult rainbow trout in sympatry or adult brook trout in allopatry. Calculated caloric intake using the mean observed stomach values was never sufficient to meet the estimated metabolic demands of adult fish at any of the sites during any of the sampling periods, despite the fact that there seemed to be sufficient food resources in the stream drift. Fulton-type condition factors of sympatric and allopatric brook trout were not significantly different, but condition factors of sympatric rainbow trout were significantly higher than the condition factor of allopatric rainbow trout. Population estimates taken in July and October indicated all populations suffered losses in biomass as standing crops decreased from 48% in allopatric rainbow trout populations to 24% in sympatric rainbow trout populations.

In summary, despite data that seemed to indicate that these populations were food limited, there was no evidence to support competition for food resources in areas where the two species coexist.

RECOVERY OF BENTHIC MACROINVERTEBRATE COMMUNITIES AFTER TEN YEARS POST-MITIGATION TO ANAKEESTA LEACHATES AND ACIDIFICATION PROCESSES

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Acidification drainage leached from a pyritic mineral rock (Anakeesta), exposed by highway construction landfill, has had detrimental effects on aquatic biota in Hemlock and McNabb Creeks of the North River basin, Monroe County, Tennessee. In addition to the absence of fish, benthic macroinvertebrate community diversity, density, and total taxa have been shown to be indicators of these adverse effects. Temporary mitigation was carried out by the Federal Highway Administration (FHWA) in 1978 when these streams were found to be devoid of fish. Preceding mitigation, streams were characterized by depressed pH and total alkalinity, elevated conductivity levels, and a high concentration of sulfates and toxic metals. An ongoing follow-up study, ten years after mitigation, reveals stream ecological characteristics typical of those identified before mitigation. Laurel Branch, Citico, and Sugar Cove, three similar unaffected creeks, were chosen as reference sites to Hemlock and McNabb Creeks in a one year follow-up study. Quantitative and qualitative benthic macroinvertebrate samples were taken monthly at one site on each stream. Site-specific physical measurements including pH and flow, specific conductance, dissolved oxygen, and turbidity were also recorded monthly. Data reveal Anakeesta-impacted streams are reminiscent of premitigation periods with decreased community diversity, density, and total taxa and a dominance of acid-tolerant genera, such as *Peltoperla*, *Leuctra*, and *Diplectrona*. A reduction or absence of more sensitive groups, including all Ephemeroptera (mayflies), was also documented in the impacted streams.

ELECTROPHORESIS OF BROOK TROUT FROM STOCKED AND UNSTOCKED GREAT SMOKY MOUNTAINS STREAMS: PRELIMINARY RESULTS

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Local anglers in the Southern Appalachians have long maintained that the native speckled trout is different from the hatchery-reared brook trout, which originated from New England. Previous scientific attempts to evaluate the taxonomic status of the southern strain of brook trout have produced conflicting results. Using the technique of starch gel electrophoresis, two previous studies concluded that southern brook trout are distinct from northern brook trout, while a third study found no differences. Because of the important management implications of the possible presence in the park of an exotic genotype, this study was initiated to examine the question of possible strain differences in GRSM streams in relationship to the stocking history of the streams. Eight streams were selected for sampling, four having no records of stocking. Eyes, liver, and muscle tissue of 25 fish from each stream (except only 6 fish from one stream) were collected and frozen in liquid nitrogen in the field. These samples were transferred to the ultracold freezer in Dr. Gary McCracken's laboratory at the University of Tennessee, where starch gel electrophoresis is being conducted. Thus far, 13 enzymes and 19 loci have been surveyed. Good results have been obtained for malic dehydrogenase, phosphoglucose isomerase, general protein, malic enzyme, glucose-6-phosphate dehydrogenase, octanol dehydrogenase, indophenol oxidase, lactose dehydrogenase, phosphoglucose mutase, and glutamic oxalacetic transaminase. From a small number of individuals from four populations, evidence seems to indicate a higher degree of polymorphism among stocked than unstocked populations, and apparent fixed differences in certain loci. It is much too early to draw any conclusions. Analyses are continuing.

SEDIMENTOLOGICAL STUDY OF THE THUNDERHEAD SANDSTONE, OCOEE SERIES, SMOKY MOUNTAINS, EASTERN TENNESSEE

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The Thunderhead Sandstone is part of the Great Smoky Group of the Ocoee Series, and has been described as a monotonous sequence of turbidity current deposits. Recent observations have revealed a complexity beneath the apparent monotonous exterior.

The Thunderhead is a thick-bedded, coarse-grained subarkosic sandstone. Within the Thunderhead are preserved numerous sedimentary structures, including small-scale (ripple) cross-lamination, large scale planar and trough cross-stratification, horizontal lamination with parting lineation, graded bedding, soft sediment deformation structures, preferential pebble alignment and imbrication, and numerous erosional structures.

The Thunderhead Sandstone can be described in terms of the Bouma sequence associated with sedimentation by turbidity currents. Formations within the Great Smoky Group can be seen in the field to intertongue laterally; therefore, these sediments are interpreted to represent sedimentation in a large submarine fan complex. Analysis of paleocurrent data from sedimentary structures with the Great Smoky Group sediments indicates a basin that was receiving sediment from multiple directions. The clastics of this ancient basin were probably derived from older rocks that were uplifted on both sides of the rapidly subsiding trough. The data indicates that the eastern margin of North America was probably active during the deposition of the Great Smoky Group submarine fan complex.

DEBRIS SLIDING IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK AS A SEDIMENT TRANSPORT PROCESS

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Aerial photography and field observations have enabled the volume of material transported from Anakeesta Ridge to be estimated. Debris sliding has been found to be a significant transportation agent.

Anakeesta Ridge is located 1.2 km (0.7 mile) north of Newfound Gap and is within the Great Smoky Mountains National Park. Anakeesta Ridge is underlain by the folded and fractured Anakeesta Formation. Much of the formation consists of dark-gray, pyritic and carbonaceous slate or phyllite (Hadley and Goldsmith 1963).

Transportational processes that are operating on the slope include creep, overland flow and debris sliding.

Aerial photographs of the study area have recorded changes in topography from 1953 to 1984. The slide scar area in 1953 was 8300 m² (89,000 ft²) with a scar head area of 3100 m² (33,000 ft²). Including the latest debris slide of 1984, the multiple slide scar area is 129,000 m² (1,390,000 ft²) with a scar head area of 57,000 m² (610,000 ft²). Based on field evidence, the average thickness of regolith removed was one meter. It is estimated that 57,000 m³ (2,000,000 ft³) of material has been transported from the Anakeesta Ridge scar heads.

The presence of log jams, distal location of angular Anakeesta Formation rocks, the dominance of poor sorting within debris fans, and rapid development of the landscape all indicate that debris sliding has had the greatest impact of all the operating transportation processes.

Reference:

Hadley, J. B. and R. Goldsmith. 1963. Geology of the Eastern Great Smoky Mountains, North Carolina and Tennessee. USGS Professional paper 349-B, pp. B1-B118. U.S. Government Printing Office, Washington, D.C.

TERRESTRIAL CAVE COMMUNITIES IN THE MAMMOTH CAVE REGION

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The main community types are near entrances where the food base is organic input of soil, litter, and animal feces (raccoon, packrat, bat and cricket). Under the Mammoth Cave (MC) Plateau, long passages and great elevational differences among few entrances result in cold-dry air input in winter and this stops decomposers and cave animals from utilizing organic input. However, some of these cold-dry entrances are bat hibernacula. This contrasts with the Sinkhole Plain headwaters of MC with shorter and shallower passages that have many entrances with stream or sinkhole inputs. This keeps organic input damp enough to support stable communities based on the most reliable organic input, cricket guano. There is more total organic input by streams, but flooding rigor is a problem for all but oligochaete-carabid beetle communities with mud crack refuges near or above the high water level. Flooding rigor is much less of a problem under the MC Plateau where vertical shafts are the main water inputs and organic debris flushes into old shafts infrequently and unpredictably. Such debris is too highly leached to support any but the most long-lived and energy-efficient species of springtail, millipede, and phalangodid. Away from streams, the same species depend on highly dispersed feces of crickets which are moving from entrances to sandy areas to mate and lay eggs. In sandy areas, cricket eggs are predated by beetles and their feces in turn support a springtail, two mites, a dipluran, a scavenger beetle, a spider, and a pseudoscorpion with the local composition depending on substrate moisture. Near entrances, moisture is a less important determinant of community composition than kinds and dispersion of feces of crickets, packrats, and raccoons and dispersion of unleached soil and litter. Study of pure patches of each food type suggests that the basis for community composition is specialization to each food type. Of 45 species, 38 have 95%+ of their total importance value (frequency + density + impact per individual) and all of their reproduction on one food type (18 months of census with T. C. Kane). To achieve 95% of importance value for other species required 2 food types (4 species), 3 food types (2 species), and 4 food types (1 species).

The basis for this specialization appears to be energy availability per area per time rather than nutritional differences among foods. Lavoie and I took dried rat feces of the same nutritional composition and ground, moistened, and shaped equal amounts into the number, size, and dispersions typical of real raccoon, packrat, and cricket feces. These experimental treatments attracted the species typical of the real fecal types (community similarity values based on importance values). In retrospect, these new results fit with a number of older observations, especially that dispersion and renewal rate of real foods of one type, such as cricket feces and packrat feces, are major determinants of local community composition. Presently I am investigating the effect of packrat feces dispersion on attraction of a staphylinid beetle predator and how this results in apparent competition between scavenger beetles and larvae of fungus gnats.

Supported by National Science Foundation grants to the author and to Lavoie with logistic and technical support from The Cave Research Foundation and 25 years of cooperation with the staff of Mammoth Cave National Park. Results of these studies can be found in: T. L. Poulson and D. C. Culver, 1969, *Ecology* 50(1):153-157; DCC and TLP, 1971, *Annales de Speleology*; T. C. Kane and TLP, 1976, *Ecology* 57(4):793-800; 1981 Proceedings of the 8th International Congress of Speleology, 56-62 (TLP) and 262-266 (Lavoie); and in the Annual Reports of The Cave Research Foundation (1975-present).

SOME IMPLICATIONS OF ARCHEOLOGICAL REMAINS IN THE MAMMOTH CAVE SYSTEM, MAMMOTH CAVE NATIONAL PARK, KENTUCKY

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The Cave Research Foundation Archeological Project has been working in Mammoth Cave National Park since 1963 with support from the Illinois State Museum Historical Society, the National Endowment for the Humanities, the National Geographic Society, the National Science Foundation, the University of North Carolina-Chapel Hill and Greensboro, and Washington University-St. Louis. Results are summarized in two books (The Prehistory of Salts Cave, Kentucky, 1969, Illinois State Museum Reports of Investigations No. 16; and Archeology of the Mammoth Cave Area, 1974, Academic Press) and numerous articles, but we are still refining earlier knowledge and accumulating new data. Our most recent research is concentrated in two different areas: (1) pre-historic mining of cave minerals and (2) the origins and early development of plant cultivation in Eastern North America.

With respect to no. 1, investigations initiated by a group of archeologists and speleologists from Indiana (John Bassett, Samuel Frushour, Cheryl and Patrick Munson, and Kenneth Tankersley) are resulting in amplification and modification of earlier conclusions. It now appears that the aboriginal cavers systematically sought not only two different sulfate minerals (mirabilite and gypsum), but also three different forms of gypsum (crust, satinspar, and selenite).

With respect to no. 2, new ^{14}C determinations on archeological material from Salts Cave Vestibule have revised some of our previous chronological understandings (see Paul Gardner's article in American Antiquity, vol. 52, no. 2, 1987, "New Evidence Concerning the Chronology and Paleoethnobotany of Salts Cave, Kentucky"), whereas continuing archeobotanical research shows that the plant remains from Mammoth Cave and Salts Cave comprise the most abundant and detailed data available on Early Woodland (ca. first millennium B.C.) plant cultivation and diet. The earliest widely accepted cultigens in the Eastern North American archeological record are gourd-like squashes (Cucurbita pepo, variety ovifera) and bottlegourd (Lagenaria siceraria)--presumably Latin American in origin--dating to approximately 2500 B.C. at the archeological sites of Phillips Spring in western Missouri, Carlston Annis in western Kentucky, and Bacon Bend in Tennessee. Although both these gourd species produce edible seeds, the fruits were probably used primarily as containers, rattles, net floats, etc. rather than as foods. The oldest cultivated food plants are indigenous species: sumpweed (Iva annua) ca. 2000 B.C. at Napoleon Hollow in west central Illinois, Chenopodium (goosefoot or lambsquarter) at Cloudsplitter and Newt Kash Hollow shelters in eastern Kentucky ca. 1500 B.C., and sunflower at the Higgs site in Tennessee ca. 1000 B.C. By 700 - 800 B.C. all these species were being grown by the prehistoric cavers who explored and mined the Mammoth Cave system (they may also have been raising another starchy-seeded plant besides Chenopodium: maygrass, or canary grass [Phalaris caroliniana]). The botanical evidence

from the big, dry trunk passages and Vestibules of Mammoth Cave and Salts Cave includes charred and uncharred plant remains (some of the latter derived from food waste in the intestines of two prehistoric bodies preserved in the cave interiors). As already noted, the archeobotanical material from these two caves provides the most abundant and highest quality information on prehistoric food production and diet presently available in Eastern North America.

A PROPOSED PROTOCOL FOR ASSESSING GROUNDWATER QUALITY USING BIOTIC INDICES IN THE MAMMOTH CAVE REGION

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This proposal is based on 25 years of personal data collection as well as on data taken by and conversations with colleagues (Barr, Griffith, Hobbs, Holsinger, Keith, Lavoie, Leitheuser, Lewis, Lisowski, Mallory, Morgan, Olson, Quinlan, Schindel and Whitman). The synthesis presented here is my own. Changes in the biota's distribution and abundance in nature give an integrated record of past pollution events, whereas laboratory bioassays (EPA protocols) or remote sensing of respiration in caged fish (Morgan) or chemical tests of water only detect pollution if measured at the time of input during spring runoff, storms, and spills. A single acute pollution event will be shown by the presence of any human pathogenic bacteria (e.g., *Yersinia*) for human waste, death of short-lived and high metabolic rate species (e.g., copepods) for heavy metals, and ulcers on fish for toxic organic chemicals. Chronic pollution will be shown by increase in abundance of isopods (≤ 1 year) and flatworms (> 1 year) and decreasing species diversity for low inputs of human/animal wastes and increases in crayfish reproductive success and shifts to more troglomorphic species of amphipods for very low levels of animal wastes or high levels of natural leached wood/leaf litter (> 5 years). Chronic input of heavy metals will, because of bioaccumulation and biomagnification, first kill or stop reproduction first of the oldest-largest individuals at the top of the food chain (fish and then crayfish). Continued input of toxic organic chemicals and pesticides may show the same effects as well as ulcers and developmental abnormalities (e.g., broken back syndrome in *Amblyopsis*, Keith). Siltation pollution, due to local construction or dams on the Green River, will decrease species diversity by homogenizing habitat (Lisowski, Poulson) and compromising species that depend on sand interstitial fauna (shrimp, Leitheuser and Whitman). These examples show that no one species is a reliable biological indicator of all kinds and rates of pollution input. Each has its advantages and disadvantages, including practical ones. Thus cavefish accumulate organics in fat and show ulcers and developmental abnormalities but their relative rarity and endangered/threatened status precludes routine sampling. Crayfish are much more abundant, readily trappable, and can be scored as to reproductive condition in the field (transparent exoskeleton) but do not store much fat and do not show field scoreable ulcers or developmental abnormalities.

Baseline data for unimpacted waters are available for aquatic habitats under the caprock within MCNP, but are not available and may be hard to obtain for cave habitats under the sinkhole plain in the headwaters of MC outside the park. There has been stability in species composition, relative abundances, and size distribution and reproduction for 25 years in three shaft/shaft master drain areas under the MC Plateau (Poulson, MACA-N-14). Differences in relative abundance of species among the three streams are due to differences in substrate composition (clay-silt-sand-gravel-rock) as well as frequency of renewal for leached organic matter. Barr, Lewis and Poulson have shorter data sets for unimpacted and septic field impacted areas near entrances, such as rimstone pools and terminal breakdown seeps. We have preliminary data from the Hawkins/Logsdon River complex out from under the caprock, both for unimpacted local tributaries fed by karst valley sinkholes and shafts and for the main streams fed by sinkhole plain drainage with diffuse non-point pollution of septic fields, fertilizer, herbicides and pesticides (Olson and Griffith). These confounding variables are partially separable by data from local caves in the drainage network. Among stream differences in Parker Cave show the local effects of sulphur pollution associated with oil/gas wells (Poulson and Keith). Upstream areas of this drainage (Walnut Hill Cave, Poulson) have only local farm types of pollution associated with crops. Cave City (aka L&N Cave) receives only domestic sewage at low levels and has had a stable community for 20 years (Poulson), whereas different downstream branches of Horse Cave have been impacted by both severe organic pollution (domestic wastes and cheese whey) and past heavy metal pollution. Lewis has started to follow the recovery of the Horse Cave system. In all of these cases, a proper perspective depends on use of detailed cave maps (CRF), detailed hydrological maps (Quinlan), and detailed maps of surface use patterns. However, we already know enough to zone even undiscovered passages based on general relationships of geology and surface topography to cave passage patterns and biological community types.

EVOLUTIONARY AND ECOLOGICAL INTERACTIONS BETWEEN THE CAVE BEETLE NEAPHAENOPS TELLKAMPFI (COLEOPTERA: CARABIDAE) AND THE CAVE "CRICKET" HADENOECUS SUBTERRANEUS (ORTHOPTERA: RHAPHIDOPHORIDAE) IN MAMMOTH CAVE NATIONAL PARK

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A predator-prey system consisting of a carabid cave beetle and a Rhaphidophoran "cricket" has been investigated in Mammoth Cave National Park, Kentucky, for 20 years by Kane, Norton, and Poulson. These previous studies have provided baseline data for the current project. Continuity of research is ensured by the National Park Service, which also protects the relatively vulnerable cave environment from anthropogenic disturbances. The main research site is located in Great Onyx Cave, where high population densities of beetles and adult crickets co-occur in time and space.

Theoretical models are being developed to explore the possible impact of beetle predation on the eggs of the cricket. Eggs are preferentially laid in sandy substrates, where the beetles dig them up. Field observations and manipulations of prey (i.e., egg) densities are being combined with laboratory experiments in order to test the predictions of the models.

A random search model has been developed that assumes that there is no information transfer between beetles. The model predicts that beetles should remove a lower proportion of eggs at high egg densities than at low egg densities. Field experiments indicate that the beetles remove the same proportion of eggs ($62\% \pm 9.4\%$ [s.d.]) irrespective of density, i.e. the proportion of eggs removed as a function of egg density is density-independent. Thus, it is probable that beetles are either not searching randomly, or are capable of obtaining information from the digging activity of other beetles. It is likely that a combination of substrate moisture constraints (eggs in areas of the cave with low substrate moisture content have 100% mortality due to desiccation) and biotic factors (such as predation intensity and egg density) determine the distribution and abundance of both the predator and the prey.

THE MECHANICS, UTILITY, AND STATUS REPORT OF THE SMALL CAVE RESOURCE INVENTORY AT MAMMOTH CAVE NATIONAL PARK

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The Small Cave Resource Inventory (MACA-N-98) describes caves and karst features in a uniform manner employing a standardized "check-off" form. Two forms are used: one for the entrance (including the twilight zone and immediate environs) and an interior form. Data recorded include: locational, physical, geological, biological, and cultural information. The form has been structured in a way which makes it useable in most commercially available data bases for storage and retrieval.

Over 200 caves and karst features are recorded in Mammoth Cave National Park and with the assistance of the Cave Research Foundation, approximately 10 percent have been surveyed and inventoried. Maps and inventories are made available for resource managers and researchers as they are produced. It is expected that the results will eventually be published in a folio format.

CAVE RESEARCH FOUNDATION: THREE DECADES OF VOLUNTEER RESEARCH AT MAMMOTH CAVE NATIONAL PARK

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Formed in 1957 to explore and study caves in Mammoth Cave National Park, the Cave Research Foundation has contributed more than 15 million dollars worth of quality research to the park. Approximately 1000 publications have resulted, including maps, monographs, dissertations, theses, hundreds of articles in refereed journals, and annual reports. Accomplishments of CRF scientists include integration of park caves into the longest cave in the world (325 miles), detailed studies of cave archeology, history, ecology, geology, hydrology, minerology, vertebrate paleontology and geochronology, and

numerous management reports. These efforts have provided, at no cost to the National Park Service, baseline data that have won Mammoth Cave National Park international recognition, including designation as a World Heritage Site. These data also provide the basis for the current resource management efforts, including the challenges of regional groundwater pollution and endangered species protection.

Staffed by more than 300 volunteer scientists, students and interested amateurs from throughout the United States, CRF efforts at Mammoth Cave are guided by a long-term national Memorandum of Understanding with the National Park Service. CRF policy is controlled by a national board of directors; research staff participate in Foundation activities through a joint venture agreement. CRF interdisciplinary research continues to contribute to the understanding of the world's longest cave through our uniquely productive partnership with the National Park Service. CRF scientists have used the model developed at Mammoth Cave to provide volunteer research, management and consultant services to more than a dozen national parks. Field research facilities are maintained at Mammoth Cave, Carlsbad Caverns, Guadalupe Mountains and Kings Canyon National Parks.

ARCHAEOLOGICAL INVESTIGATIONS AT THE FLOYD COLLINS BIRTHPLACE, EDMONSON COUNTY, KENTUCKY

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In October 1987, a domestic water line was placed across a portion of the William Floyd Collins Birthplace/Crystal Cave Complex located in Edmonson County, Kentucky. Prior to excavation, plat maps were examined to determine the potential this action would have in disturbing structures associated with the life of Floyd Collins. The water line was excavated mechanically using a "Ditch Witch" that produced a transverse profile of the site. Though no features were encountered, these methods produced a small but significant assemblage. Subsequent analysis of this highly fragmented material culture indicated the presence of the structure where William Floyd Collins may have been born and spent the first 20 years of his life. Additionally, this study has served to: (1) further assess the applicability of artifact patterning studies and mean date determinations to rural domestic sites; (2) demonstrate the utility of applying readily available information on commonplace artifact forms to date structural elements of standing structures; and (3) permit a glimpse of the material possessions and lifeways of a struggling farm family in turn-of-the-century Kentucky.

SLOAN'S CROSSING POND, MAMMOTH CAVE NATIONAL PARK: A UNIQUE ALGAL HABITAT FOR SOUTHCENTRAL KENTUCKY¹

Gary E. Dillar, Western Kentucky University

Sloan's Crossing Pond, apparently an abandoned beaver pond, is a shallow, dystrophic pond located in Mammoth Cave National Park, Edmonson County, Kentucky. The habitat is unusual for the karst region in many respects. The bottom consists of a bed of slate overlain by unconsolidated sediment of varying depth. Alkalinity (<20 mg/l) and pH (4.5-6.5), unlike more typical habitats of the region, are low. Most of the surface is covered by a dense growth of water shield, Brasenia schreberi Gmelin, and bladderwort, Utricularia gibba L., with the margins dominated by three-way sedge, Dulichium arundinaceum (L.) Britton, common cat-tail, Typha latifolia L., and button bush, Cephalanthus occidentalis L.

The highly diverse algal flora is, in general, more representative of that associated with so-called "brown water ponds" of the southeastern Coastal Plain. Additionally, a number of algal taxa particularly of the Chrysophyceae and Xanthophyceae, infrequently reported from the conterminous United States, occur there. Systematic and ecological data will be presented for, among others, the chlorophytes, Gloeotaenium loitlesbergerianum Hansgirg and Pachycladiella (= Pachycladon) umbrina (G. M. Smith) P. Silva; the xanthophyte, Chadefaudiothrix gallica Bourrelly; and the chrysophytes, Chrysodidymus synuroides Prowse [includes C. gracilis Prowse] and Cyclonexis annularis Stokes.

¹ Supported by the Faculty Research Committee, Western Kentucky University.

CARTOGRAPHIC DELINEATION OF THE CAVES OF MAMMOTH CAVE NATIONAL PARK

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Since its formation in 1956, the Cave Research Foundation has explored and mapped hundreds of miles of passage within and around Mammoth Cave National Park. One of the first products of this effort was the Flint Ridge Folio depicting caves under Flint Ridge within the park as of 1964. Since that time, maps have been produced at a variety of scales for a variety of purposes. These maps include line maps of the entire system at scales of 1:24000 and 1:12000, as well as more detailed maps at scales of 1:1200 and 1:600. The 1:12000 map is especially interesting, consisting of different colored lines indicating levels projected on a two-tone topographical background. A new system of maps at 1:600 is presently underway and will eventually result in a new, much more detailed folio of maps.

Field techniques have been modified over the years to improve the quality of the data taken within the cave. Surveys are primarily done by compass, clinometer, and tape methods with backsights taken at all stations. Passage sketching is typically done at a field scale of 1:240, with the sketcher also making biologic, geologic, and historic notations. Survey error is usually less than 0.5% and surveys are closed by standard surveying methods to established datum points, frequently USGS benchmarks.

There has been, over the years, considerable interest in doing three dimensional computer modeling with the survey data. Progress is slow on this due to funding and personnel limitations. A programmer or data manipulator must also be very familiar with caves, and this cave in particular, if the final product is to be useful. At present, computers serve to reduce and manipulate survey data but are not used in drafting per se; maps are still essentially hand-drafted.

Lastly, a number of smaller caves within the park have been surveyed. Several of these are over 1 mile in length, but most are relatively short. An active program for drafting these is also underway.

WILDLIFE RESEARCH IN GREAT SMOKY MOUNTAINS NATIONAL PARK

Julia Thomas, Science Division, Great Smoky Mountains National Park, Gatlinburg, TN 37738

The Science Division has been involved with two wildlife research projects in the past year. The first is the high elevation small mammal survey, done through a cooperative park study subagreement with Dr. Roger Powell at North Carolina State University. The purpose of this study is twofold. As the name indicates, the primary purpose is to assess the variation and diversity in small mammal populations in the high elevations of the Great Smoky Mountains National Park and to compare those results with another study done by Tommy Smith in 1984. If populations are declining, how much of that decline can be related to the decline in the high elevation spruce-fir forest? The other purpose for this survey is to assess the feasibility of reintroducing the fisher (*Martes pennanti*). The fisher's food supply would consist of small mammals; therefore, the two purposes mesh nicely. Powell is looking at prey species and employing a habitat suitability index for fisher. He will be able to give a preliminary recommendation regarding fisher reintroduction by this winter.

The other project in wildlife is the completion of the European wild hog bait enhancement study. Right now, we are in the field-testing phase of bait evaluation. The top five baits from the penned tests are being evaluated in an incomplete paired block design which allows each bait to be tested against every other. As one other speaker expressed it, I am finding "statistical support for the obvious." So far, hogs prefer corn mash, corn soaked in beer, corn with spoiled milk, and corn with strawberry or walnut flavorings, in that order. Further and final analysis with respect to males' preferences versus females' preferences/seasonal preferences should be completed by September 1988.

STATUS OF THE ENDANGERED INDIANA BAT, MYOTIS SODALIS, IN GREAT SMOKY MOUNTAINS NATIONAL PARK

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Fifteen species of bats occur within Tennessee and/or North Carolina; nine species have been reported from Great Smoky Mountains National Park. They are: Myotis lucifugus, little brown bat; Myotis septentrionalis, northern long-eared bat (formerly Myotis keenii, Keen's bat); Myotis sodalis, Indiana bat; Myotis leibii, small-footed bat; Pipistrellus subflavus, eastern pipistrelle; Eptesicus fuscus, big brown bat; Plecotus rafinesquii, Rafinesque's big-eared bat; Lasiurus borealis, red bat; and Lasionycteris noctivagans, silver-haired bat. The endangered Indiana bat hibernates in only two GSMNP caves, both in Blount County, Tennessee. The total population hibernating in these two caves numbered an estimated 11,820 bats (11,600 and 220) when last checked. This number represents ca. 46% of the entire known Tennessee Indiana bat hibernating population.

CHANGE IN AN AVIAN COMMUNITY AFTER LOSS OF A DOMINANT CANOPY TREE SPECIES

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Comparison of censuses of breeding birds taken 12 yr apart in a high elevation coniferous forest show that the avian community changed substantially in response to the death of a dominant canopy tree caused by the invasion of an exotic insect. The balsam woolly aphid (Adelges piceae) had by 1986 killed most of the endemic fir (Abies fraseri) on Mt. Collins and other ridges of Great Smoky Mountains National Park. Data from 1974, before the invasion, document its impact on the composition and physical structure of the plant community and on the avian community. Density of Fraser fir was reduced to one-tenth of its earlier density by 1986 (5 years after adelgid invasion) and density of red spruce (Picea rubens) was reduced as well, chiefly by windthrow. Understory shrubs were also affected. The volume of canopy, measured photographically, was reduced to at least half its 1974 level. A remarkably parallel change occurred in the avifauna: 1986 densities were 37% lower than those of 1974 for all species together. Of species for which quantitative density estimates were possible, 10 of 11 showed reductions in densities by an average of 41%. Reductions were most pronounced in canopy species of intermediate abundance; near-ground and trunk-foraging species were less affected. Some species densities were low enough that continuing changes in the plant community will make local extinctions possible. Invasions of birds characteristic of open, disturbed and second-growth forests are just beginning. These changes are similar to those in other studies of forests disturbed by pathogens and logging; the magnitudes of the changes are outside the range of normal year-to-year variation and are not explained by regional trends. This simple avian community shows surprising stability in the face of a gross alteration of the habitat, in spite of the island-like distribution of high elevation forest. The extent of relatively pristine forest in the Great Smoky Mountains, and population pools in other forest types, help explain this stability.

MOVEMENTS AND SURVIVAL OF PEN-REARED BLACK BEARS

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Since 1982, 16 pen-reared black bears (Ursus americanus), 10 from the Municipal Black Bear Habitat at Ober Gatlinburg, Tennessee, have been released into the wild. Little data has been gathered from these bears. On 2 February 1988, the Tennessee Wildlife Resources Agency obtained three male black bears from the Municipal Black Bear Habitat. The bears were fitted with Telonics break-away radiocollars and placed in wooden box dens on the Laurel Fork Wildlife Management Area, Carter County, Tennessee. The objectives of this release were: (1) to determine if pen-reared black bears can live in a natural environment, (2) to evaluate a winter release of pen-reared black bears, and (3) to monitor the movements, home range, and survival of pen-reared black bears in the wild. To date, 27 locations have been obtained for the three bears using triangulation and aerial and ground homing techniques. Seventeen visual observations

have been made. All three bears emerged from the wooden box dens within 24 hours. On 14 March 1988, bear #881 was observed hibernating under a stump. Due to persistent nuisance activity, bears #880 and #881 have been removed from the study area. On 4 May 1988, bear #880 was destroyed. On 9 May 1988, bear #881 was captured and returned to the Municipal Black Bear Habitat. The intent is to continue monitoring the movements of the remaining bear to determine his success in a natural environment.

BLACK BEAR BAIT-STATION SURVEY ON THE PISGAH NATIONAL FOREST, NORTH CAROLINA

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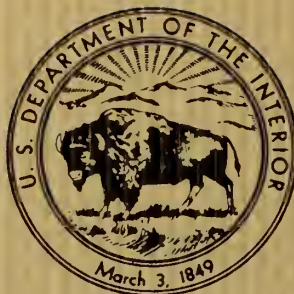
Bait-station surveys have proved to be a reliable and relatively inexpensive method to monitor density, distribution and activities of black bears (*Ursus americanus*). Three bait-station lines were established and monitored on the Pisgah National Forest from 1981-1987 with 22, 25, and 30 bait-sites, respectively. The surveys were conducted in spring, summer and fall in 1981-1983 and in the summer only from 1984-1987. The objectives of this survey were to analyze the relationships between visitation and various sources of variation and to determine the black bear population density and distribution. PROC GLM (General Linear Models) and other SAS programs were used in the statistical analysis. The mean visitation rate over all seven years was 19.5%. Visitation rates differed seasonally between years ($F = 6.13$, $p = 0.0001$) with higher visitation rates in summer (21.2%) and lower rates in spring and fall (12.7% and 11.1%, respectively). Lower mean visitation rates in 1981-1983 may be due to these seasonal variances. Significant differences in visitation rates were found for elevation ($F = 36.26$, $p = 0.0001$), distance from roads ($F = 6.07$, $p = 0.014$), and distance from trails ($F = 9.23$, $p = 0.0024$). Bear visits to sites on various types of roads showed a significant difference ($F = 13.72$, $p = 0.0001$) with a preference for open access 4WD roads in contrast to open access paved and gravel roads and gated roads. Bait-sites on the bear sanctuary had significantly higher visitation rates ($F = 28.8$, $p = 0.0001$) than outside the sanctuary (28.3% vs. 18.8%). 12.4% of the visits were on the boundary of the sanctuary. Differences in visitation rates by road type and bear sanctuary may have been influenced by other variables. Further analysis will be done to evaluate these and other interactions. The same statistical analysis will be done on bait-line data from Great Smoky Mountain National Park and from the Tellico district of the Cherokee National Forest. The ultimate intent is to combine all three data sets into one file for further analysis.

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